ENGINEERS AUSTRALIA
Western Australia Division

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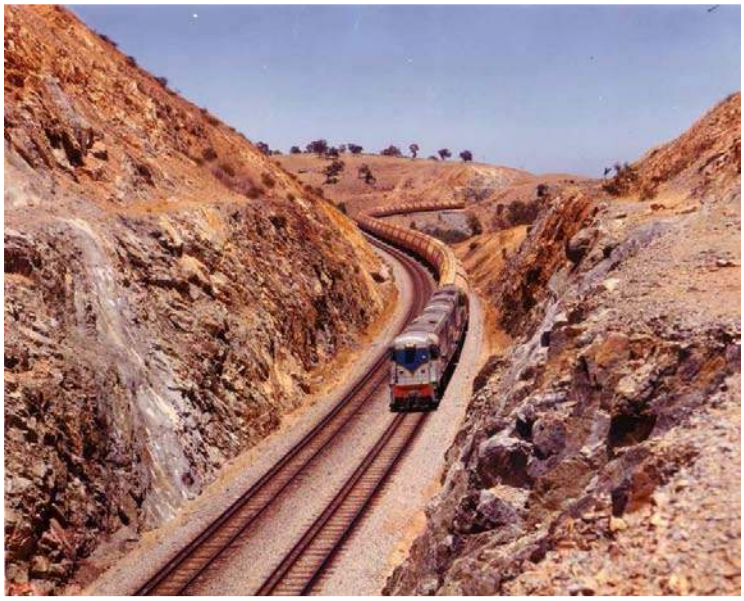
NOMINATION OF

WESTERN AUSTRALIAN STANDARD GAUGE RAILWAY

FOR A

ENGINEERING HERITAGE AUSTRALIA HERITAGE RECOGNITION AWARD



Wheat train on dual gauge track passing through cutting in the AvonValley

PREPARED BY ENGINEERING HERITAGE WESTERN AUSTRALIA
ENGINEERS AUSTRALIA
WESTERN AUSTRALIA DIVISION

September 2011

CONTENTS

1 Introduction

The original 635 km narrow gauge railway from Perth to Kalgoorlie was built in the 1890s to mainly serve the Eastern Goldfields. Since the beginning of the 20th century the standardisation of the railway gauge throughout Australia received the investigation and consideration which such an important national problem deserved. However, apart from the Trans Australian Railway, completed in 1917 as a Federation commitment, little was achieved. In 1912 the Commonwealth Government proposed a standard gauge (4 ft 8½ in or 1435 mm) railway from Fremantle to Kalgoorlie, to be completed at the same time as the Trans Australian Railway, but it did not proceed due to a lack of finance.

The catalyst for the Western Australian Standard Gauge Railway (SGR) was the conclusion of an agreement in 1960 between the Western Australian Government and BHP Co Ltd, for the establishment of an integrated iron and steel works at Kwinana, south of Fremantle, contingent on the construction of a standard gauge railway between Koolyanobbing and Kwinana before the end of 1968. The agreement envisaged the haulage of an estimated 1.1 million tons of iron ore per annum from BHP's Koolyanobbing deposit to the proposed steelworks. Subsequently this commitment formed the basis for an agreement between the Commonwealth and State Governments to jointly fund rail gauge standardisation between Kalgoorlie and Perth (including Kwinana).

The majority of the work was carried out by contract. The railway earthworks, bridgeworks and mainline track works were split into various packages eg. Kwinana to Midland, Midland to Northam, Northam to Merredin etc. Separate contracts were let for marshalling yards, freight terminals, buildings, loco depot. The total cost of the project, executed between 1962 and 1972, comprising 65 major and over 30 minor contacts, was of the order of $ 160 million.

The adoption of the Avon River valley route through the Darling Ranges from Northam to Midland for both narrow and standard gauge trains, enabled the abandonment of the steeply graded and sharply curved narrow gauge alignment from Bellevue over the Darling Scarp (through the Swan View tunnel) to Spencers Brook. The AvonValley alignment has significantly more favourable grades and flatter curvature. The track is double dual gauge (dual signifying that each line has three rails) carrying both narrow and standard gauge (1067mm and 1435mm) trains. Double tracks allow a dedicated train in each direction. Under this arrangement, all trains of both gauges to and from the Perth metropolitan area to the central wheat−belt, goldfields and interstate have the advantage of flatter grades and improved transit times. Complex engineering planning and field operations were involved in building this line and keeping the old narrow gauge track operating while the dual track was being constructed and commissioned.

The construction of the SGR set in motion a considerable stream of economic and social benefits in Western Australia. It finally completed the standard gauge connection with South Australia, removing the need for interstate passengers to change trains at Kalgoorlie and put an end to the costly transfer of goods at the Parkeston freight terminal near Kalgoorlie. Journey times between Kalgoorlie and Perth were reduced to half of those taken on the narrow gauge track.

From a historical perspective the construction of the SGR brought Western Australia into the modern era of railway construction and operation.

2 Statement of Significance

The completion of the Western Australian Standard Gauge Railway project was of considerable significance because finally the breaks in railway gauge which had hampered trade and passenger traffic between the Australian states were eliminated. The introduction of the standard gauge into Western Australia, west of Kalgoorlie, led to important changes in the planning and development of the Perth metropolitan area.

The direct standard gauge line to Kwinana to serve the BHP developments attracted other major industries to the area, including a nickel refinery and fertiliser works. As a consequence the Fremantle Harbour Board further developed Cockburn Sound as its outer harbour for the handling of bulk materials, in particular Cooperative Bulk Handling's location of its grain export terminal.

The economic advantages to Western Australia of the Standard Gauge Railway project were evident soon after the completion of the standard gauge across the continent. In the financial year ending June 1974, four years after the standard gauge was opened, interstate rail traffic increased by 35%. Ten years later the amount carried by rail was six times what it had been in 1974.

The Indian Pacific passenger service which commenced operation in 1970 is one of the few railway services in the world which crosses a whole continent from east to west and is the only one on which passengers can travel the full distance between sea-board cities without changing trains.

There were a number of notable technological achievements and contributions to engineering practice resulting from the design and construction of the standard gauge railway. They included the development of techniques to excavate deep cuttings through the Avon Valley in deeply weathered Darling Range granites, track laying techniques incorporating factory flash butt welding of 110 metre rail lengths, the use of standard prestressed concrete bridge beams and the successful use of locally occurring fine grained "bull-dust" soils for embankment construction in the eastern section of the railway.

3. Heritage Recognition Award Form

The Administrator
Engineering Heritage Australia
Engineers Australia
11 National Circuit
BARTON ACT 2600

Name of Work: Western Australian Standard Gauge Railway Project

The above work is nominated for an

Engineering Heritage Recognition Award

Location, including address and map grid reference:

This nomination refers to the standard gauge railway link between Kwinana and Kalgoorlie in Western Australia, completed in 1972, which finally completed the standard gauge rail link to South Australia. The work comprised railway earthworks, bridgeworks, mainline trackworks, associated infrastructure such as marshalling yards, freight terminals, locomotive depot and associated buildings and standard gauge locomotives and rolling stock.

Kwinana: 32° 15' 30" S, 115° 45' 00" E
Kalgoorlie: 30° 44' 44" S, 121° 27' 59" E

Owner: The Western Australian Government Railways Commission, Department of Transport, GPO Box C102, Perth Business Centre WA 6839

The Owner has been advised of this nomination and a letter of support is attached.

Access to Site: There is a daily passenger service between Perth and Kalgoorlie and motor vehicle access to the mainline can be arranged with the permission of the Owner.

Nomination Body: Engineering Heritage Western Australia, Engineers Australia, Western Australia Division

.....
Don Young, Chair of EHWA

Date 23 September 2011

4 Owner's Letter of Agreement

Government of **Western Australia**
Public Transport Authority

OWNER'S LETTER OF AGREEMENT

The Administrator
Engineering Heritage Australia
Engineers Australia
PO Box 6238
Kingston ACT 2604

Sir/Madam

Western Australian Standard Gauge Railway
Nomination for Engineering Heritage Recognition Award

This letter accompanies the nomination by Engineering Heritage WA to Engineering Heritage Australia of the Western Australian Standard Gauge projects for a heritage recognition award.

We are very pleased to support this initiative of Engineering Heritage WA and if the nomination is successful would be happy to sponsor the design and manufacture of an interpretation panel and assist with the organization of a dedication ceremony.

If you have any queries please contact Peter Martinovich on 08 9326 2374 or peter.martinovich@pta.wa.gov.au.

Yours faithfully

Mark Burgess
MANAGING DIRECTOR

22 September 2011

Public Transport Centre, West Parade, Perth, Western Australia 6000
PO Box 8125, Perth Business Centre, Western Australia 6849
Telephone (08) 9326 2000 email enquire@pta.wa.gov.au
www.pta.wa.gov.au
ABN - 61 850 109 576

5 Western Australia and the trans-continental railway: a brief history

5.1 The Trans-Australian Railway

The original 618 km long narrow gauge (NG) railway from Fremantle to Kalgoorlie was completed to Kalgoorlie in 1897. At that time the 3ft 6in gauge was used on all Western Australian railways but there was continuing debate in all the Australian mainland colonies about the standardisation of railway gauges. By an unfortunate accident of history the five mainland states had built their railways on three different gauges. Queensland and Western Australia had built narrow gauge (NG, 3ft 6in) railways; New South Wales standard gauge (SG 4ft 8½in) and Victoria broad gauge (BG 5ft 3in) while South Australia had both broad gauge and narrow gauge.

In 1897 and, again in 1903, committees representing the railway engineers-in-chief of the mainland colonies (states) recommended that a standard gauge (SG) of 4ft 8in be adopted for the proposed east-west trans-continental railway. Also in 1903, at the suggestion of Sir John Forrest, the Federal Minister for Home Affairs, the Western Australian Government passed a Trans-Australia Railway Enabling Act to encourage the Federal Government and the other states to take action on the proposed Port Augusta to Kalgoorlie SG railway. The same enabling act also provided for the construction by the state of a SG railway from Fremantle to Kalgoorlie, although the authority of this Act would become void if the Commonwealth had not commenced its railway within five years which was the circumstance which prevailed.

The Kalgoorlie to Port Augusta Railway Act finally passed through the Commonwealth Parliament in December 1911 and work began on the railway in 1912. In the same year the Western Australian Government advised the Commonwealth that it planned to construct a standard gauge railway from Fremantle to Kalgoorlie which it intended to have completed at about the same time as the Trans-Australian Railway. The proposed route through the metropolitan area was separate from the existing NG line and included a tunnel under part of Kings Park and a bridge over the Narrows. However, in 1914, because of other pressing developmental schemes, the State Government put the proposal for the SG railway in abeyance and the money authorised was re-appropriated.

After the completion of the Trans-Australian Railway from Kalgoorlie to Port Augusta in October 1917 it was possible to travel by train across the continent from Perth to Sydney but, east of Port Augusta, it was a very circuitous route. Four changes of railway gauge were required to cross the continent -- at Kalgoorlie, Port Augusta, Terowie (South Australia) and Albury (Victoria).

5.2 Proposals of the 1921 Royal Commission

In 1921 a Royal Commission called for by a conference of Commonwealth and state ministers recommended the construction of SG railways from Fremantle to Kalgoorlie, from Port Augusta to Adelaide and from Sydney to Brisbane, together with the conversion to SG of all broad gauge (BG) lines in Victoria and South Australia. Not surprisingly, both Victoria and South Australia found difficulties in the proposals and only the Sydney to Brisbane SG line was built (1925). Ten years later, after further negotiations, the Commonwealth extended the SG line from Port Augusta to Port Pirie and South Australia extended the BG line from Adelaide to Port Pirie (1937).

Meanwhile the gap in a possible 'direct' trans-continental route between Port Pirie and Sydney had finally been closed. In 1887 to serve the mines at Broken Hill South Australia had built a NG line from

Port Pirie to Cockburn on the NSW border which was extended to Broken Hill by a private company Silverton Tramway Company (1888). In 1919 New South Wales built a SG railway from Broken Hill to Menindee on the Murray River to rail emergency water supplies to the city and its mines. In 1927 the missing link in the east-west railway was closed when the NSW SG line was extended from Condobolin to Menindee.

5.3 Sir Harold Clapp's Report and the Wentworth Committee's Proposals

During the Second World War heavy military traffic exposed the deficiencies of the Australian railways caused by the breaks of gauge between states. After the war Prime Minister Chiffley appointed Sir Harold Clapp Director-General of Land Transport with a brief to report on the standardisation of Australian railway gauges. Clapp's 1945 plan was more ambitious than the 1921 Royal Commission's proposals. In addition to the construction of a Fremantle to Kalgoorlie SG railway Clapp recommended the conversion to SG of the whole of South Australia's railway system, both NG and BG, together with the whole of Victoria's BG system. The east-west route from Port Pirie to Broken Hill was also to be converted to SG which would require acquisition of the private railway of Silverton Tramway Company. Although the national interest was paramount in the Clapp plan, state interests prevailed when NSW refused to become a party to a plan which mainly benefited other states.

One positive outcome for Western Australia from Clapp's proposals was the financing of a survey for an alternative railway route through the Darling Range along the Avon Valley from Upper Swan to Toodyay which located a practicable new route with favourable grades.

In another attempt to rationalise the various railway gauges in Australia, the Menzies Government appointed a Rail Standardisation Committee chaired by W.C. Wentworth. In 1956 the Committee recommended the construction of three priority SG railways, from Melbourne to Albury (at the River Murray boundary with NSW), from Adelaide to Broken Hill via Port Pirie and from Fremantle and Perth to Kalgoorlie. Following the Wentworth Report the Commonwealth made a Railway Standardisation Agreement (1958) with Victoria and New South Wales to carry out standardisation of the heavily trafficked Melbourne to Albury line which was completed in 1962.

5.4 The 1961 Railway Standardisation Agreement

Construction of the other two priority SG railways recommended by the Wentworth Committee was delayed due to the lack of suitable short term economic justification. This was provided for the Western Australian project when, in 1960, the State Government concluded an agreement with B.H.P. Co. Ltd for the development of an integrated iron and steel works at Kwinana, contingent upon the construction before the end of 1968 of a SG railway from Kwinana and Fremantle to Kalgoorlie with a spur from Southern Cross to the Koolyanobbing iron ore deposits. In 1961 the Railway Standardisation Agreement between the Commonwealth and the Western Australian Government was concluded and construction started in the Avon Valley at Upper Swan in November 1962.

5.5 The Kalgoorlie to Kwinana Standard Gauge Railway (SGR) Project

The Project was a major undertaking which required a planning commitment of considerable magnitude and complexity. A special planning section was established by the Western Australian Government Railways (WAGR) and a senior departmental officer, the 'Co-ordinator of Standard Gauge Planning', was made responsible for the co-ordination of all aspects of planning including internal WAGR branches, consultants, other departments and organisations.

Because of the magnitude of the work, in November 1961 the WAGR appointed engineering consultants Maunsell and Partners to assist with planning, and to carry out the design and to supervise the construction of the major part of the civil engineering work.
The responsibilities for the various works and requirements are indicated in general terms in the following table which also shows the financial proportion of the various areas of responsibility.

Work carried out or equipment supplied	***Financial %***	***Responsibility***
Major civil engineering contracts (not affecting departmental operations)	41%	Design and supervision of contracts by Maunsell and Partners
Civil engineering works affecting departmental operations	7%	New works division of WAGR civil engineering branch
Service and road diversions, telecommunication line construction	4%	Various Government departments (occasionally local authorities and private concerns)
Signalling telecommunications, lighting and power	7%	WAGR signal & telecommunications sub-branch. The majority of work was carried out by contract
Rolling stock	22%	WAGR mechanical engineering branch. Majority of work by contract
Track materials	16%	WAGR stores branch on civil engineering branch demands
Land acquisition	3%	WA Public Works Department to WAGR Civil Engineering Branch specification

5.6 Variations to the SGR Agreement

Three important variations were made to the Agreement which, in November 1963, were incorporated in revised schedules to the 1961 Act.

5.6.1 Midland-Northam railway via Avon Valley: increase in capacity

The Commonwealth and the State agreed that double dual gauge track should be provided in lieu of the single dual gauge track allowed for in the 1961 Agreement as the latter would have inadequate track capacity to accommodate anticipated future traffic.

5.6.2 Variation of the Route in the Perth Metropolitan Area

Under the 1961 Agreement the standard gauge railway, after emerging from the Avon Valley and passing through Midland, separated into two branches at West Midland. The northern branch followed the existing NG line through central Perth to Fremantle port, while the other branch headed south-west to Kwinana crossing the south-western railway at Kenwick. To build the SG line along the existing NG alignment through the city would have been very costly requiring the re-routing of existing services and the reconstruction of bridges. Moreover, in order to obtain the required I in 100 grade, parts of the existing railway formation would have had to be lowered.

The route variation realigned the southern branch from West Midland to provide SG access to both Kwinana and Fremantle. The northern branch, along the existing NG formation, under the variation

was to be provided only as far as East Perth where the SG passenger terminal was to be located. The southern branch from West Midland followed the original Agreement route as far as Kenwick where it was rerouted further north than before to Cockburn Junction, near Spearwood which is 10km south-west of Fremantle harbour. At Cockburn Junction it separates into two branches. One branch goes northwards round the western end of Fremantle town and crosses the Swan River on a recently built bridge into the marshalling yard of the port at Leighton. The other branch from Cockburn Junction went southwards to Kwinana. (See page 11 - Westrail in the Metropolitan Area − 1976)

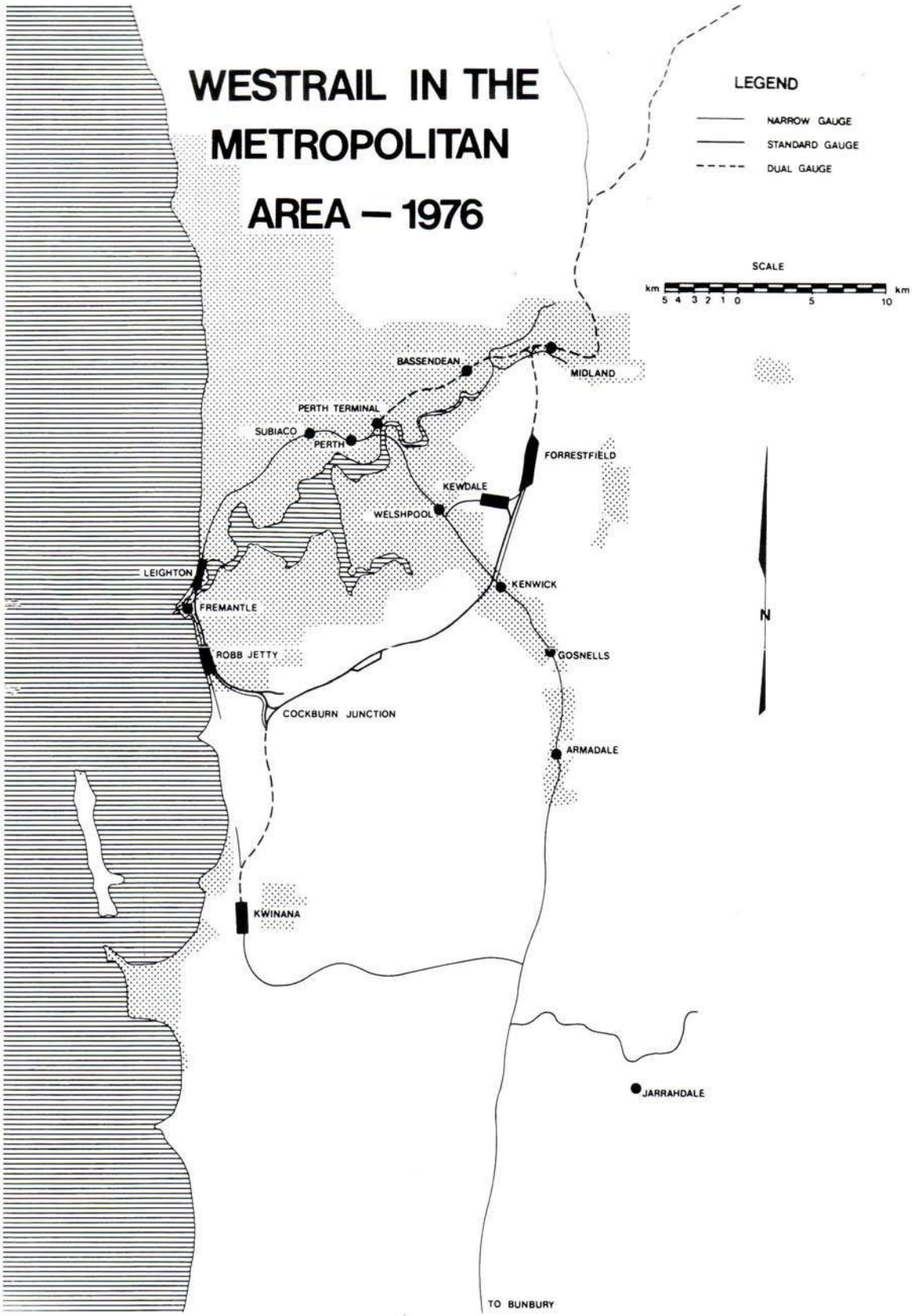
The ruling grade on the new route to Fremantle from Cockburn Junction to Leighton was 1 in 150 which became the new limitation on traffic to the port of Fremantle. This grade was an improvement on the 1 in 100 obtainable on the route originally proposed on the north side of the river. The route variation also reduced the cost of construction by approximately $4 million.

5.6.3 Variation of the Mainline Route to go via Koolyanobbing

The 1961 Agreement proposed that the SG route from Southern Cross to Kalgoorlie should follow the existing NG railway and that a 55 km long spur line should be built from Southern Cross to the Koolyanobbing iron ore deposits parts of which BHP proposed to mine. To obtain the ruling grade of 1 in 150 along the old NG route would require expensive earthworks and numerous deviations as it would have to cross a number of north-south ridges as well as numerous salt lakes and a notorious boggy area east of Southern Cross. The alternative route ran through unmapped virgin bush from Koolyanobbing directly to Kalgoorlie, joining the old NG route at Kurrawang, 15 km west of Kalgoorlie. The only obstacle on the route was an area of high sand plain north of Bullabulling, 80 km west of Kalgoorlie, across which field parties established the lowest saddle and also set up ground controls for an aerial survey. The final alignment, established by photogrammetry and accepted as a variation to the Agreement, was approximately 50 km shorter than the original route and its adoption reduced the cost of construction by approximately $4.8 million.

5.7 Standardisation Master Plan

In the 1961 Agreement the standardisation works were set out in broad outline only. As the works proceeded and became more complex it became more difficult for the officials of both governments to agree about which parts of the works were ‘standardisation works’ and which were ‘state betterment works’. Eventually the consulting engineering company, Maunsell and Partners, was commissioned to prepare standardisation master plans describing every aspect of the works which were needed. The company was also required to estimate the total cost of the works and to determine which works were ‘standard gauge works’ under the Agreement and which were ‘associated works’ to be carried out by the State although possibly required to ‘integrate effectively the two gauges to provide a viable system’. The consultants estimated that the total cost would be $158 million (including an allowance for inflation) of which $130 million was to be considered ‘standard gauge works’ and $28 million ‘associated works’. The Red Master Plan (as it was known by the colour of its cover) was presented to both governments in March 1966 and was accepted by the Commonwealth in September 1966. The total cost of the project (finalised in 1977) was very close to the estimate at $157 million.


WESTRAIL IN THE METROPOLITAN AREA – 1976
LEGEND
NARROW GAUGE
STANDARD GAUGE
DUAL GAUGE
SCALE
km 5 4 3 2 1 0 5 10 km
BASSENDEAN
MIDLAND
PERTH TERMINAL
SUBIACO
PERTH
FORRESTFIELD
KEWDALE
WELSHPOOL
LEIGHTON
KENWICK
FREMANTLE
ROBB JETTY
GOSNELLS
COCKBURN JUNCTION
ARMADALE
KWINANA
JARRAHDALE
TO BUNBURY
N

6 Description of the Project

6.1 Avon Valley: Midland to Northam

Construction began in November 1962 on the first and probably the most difficult section of the project, a new route through the Darling Range. Forty kilometres of this alignment was confined within the narrow, steep-sided gorge of the Avon Valley. Tenders were called for contact C1 which provided for two bridges across the river near Bells Rapids. Thiess/Perron Bros submitted an alternative (and more competitive) tender deleting the two bridges and replacing them with two large cuttings. (See page 13). Tenders were recalled with the earthworks option and subsequently Thiess/Perron Bros was awarded C1A contract for the work between Millendon and Smiths Mill Hill. Contact C2, awarded to Leighton, incorporated an exceptionally deep cutting at the Windmill Hill site, between Toodyay and Northam, where the cutting was 100 ft (30.5 m) deep on the formation centre line. The diagram on page 14 shows the location of the main civil engineering contracts between Midland and Northam.

Approximately 70% of the excavation in the Avon Valley route was in rock which was heavily jointed and faulted and was decomposed to a considerable extent, necessitating variations in batter slopes and benching in the deeper cuts. Rock bolting also was used in two cuttings. Extensive drainage works were provided to protect the formation from damage by sheet flow during heavy winter rains. Contour drains were built above the cuttings to deflect flow into drainage culverts. The winter of 1963 was the wettest since 1946. The Avon rose rapidly and stayed high for two months making earthworks in the valley virtually impossible. Precast concrete units at two of the Avon River bridge sites were damaged by floodwaters and had to be replaced. Construction of the railway formation through the Avon Valley took over two years whereas the tracklaying, signalling and telecommunications in the valley were completed in less than a year.

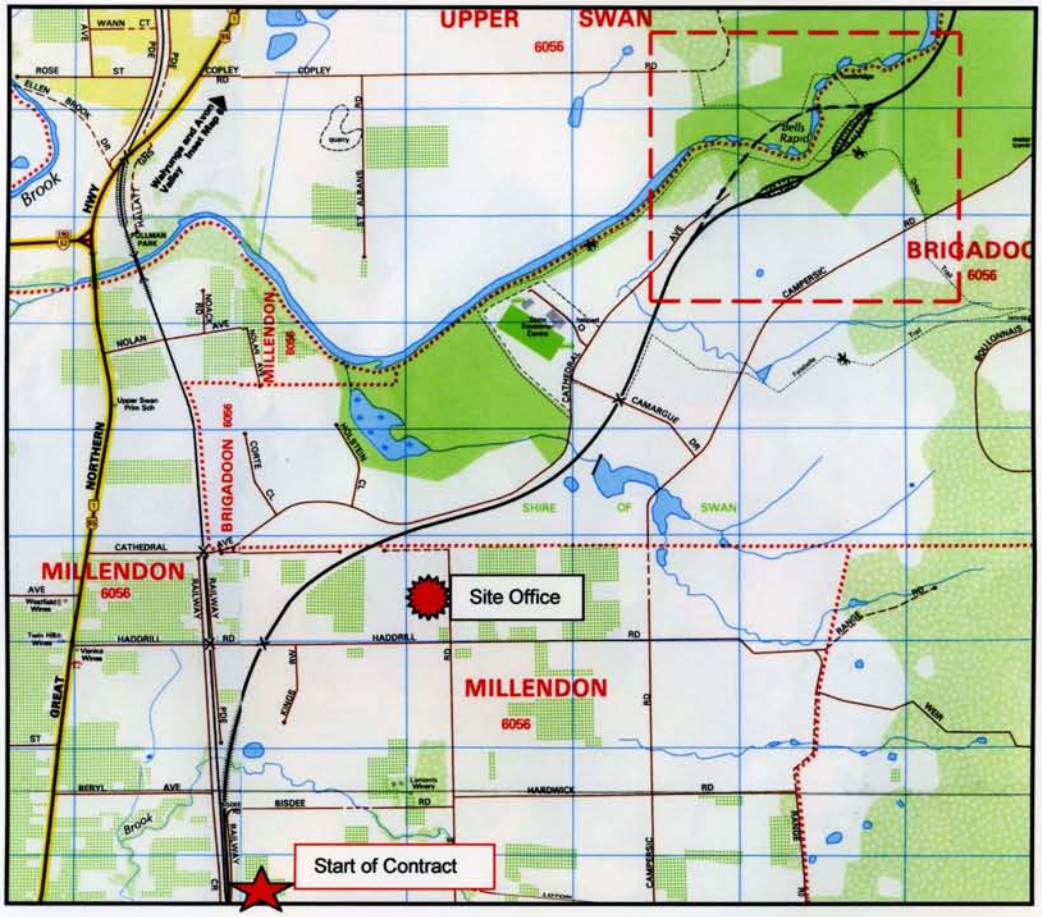
6.2 Toodyay and Northam

Staging of the works through Northam was complicated because no interruption to traffic through this junction could be permitted. A major new marshalling yard, the Avon Yard, serving both gauges was built 3 km west of Northam, at the eastern end of the double dual gauge line through the Avon Valley,. The existing NG lines which converge on Northam from the north and south were brought into the yard together with the SG line from the east. Next to the yard Co-operative Bulk Handling built a major grain transfer and storage facility of 24,000 cubic metres capacity, designed to transfer grain from NG to SG wagons for transport to Fremantle for export.

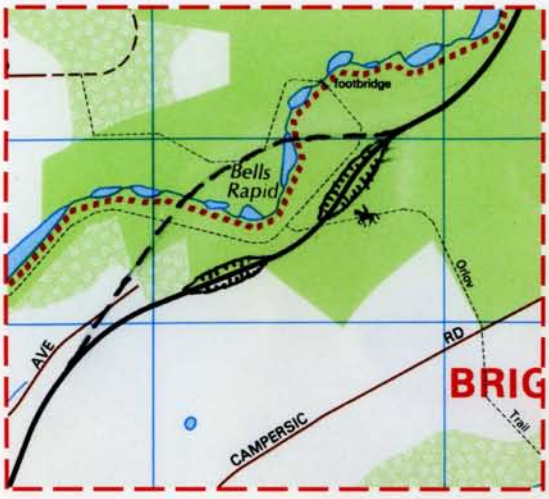
Connections to the NG lines and the route of the SG line through Northam required some major bridge works, involving two crossings of the Avon at Northam, another Avon crossing by the Calingiri&Miling NG line at Toodyay and a rail over road crossing at Northam. Each of the four bridges consisted of six 100 ft standard prestressed concrete spans. Each was founded on bases supported on 450 mm driven steel tubular piles filled with reinforced concrete.

STANDARD GAUGE RAILWAY PROJECT

AVON VALLEY SECTION - CONTRACT C1A



The above map shows the first 6 km of Contract C1A after leaving the Midland Railway



This enlargement shows the deviation proposed by Thiess.

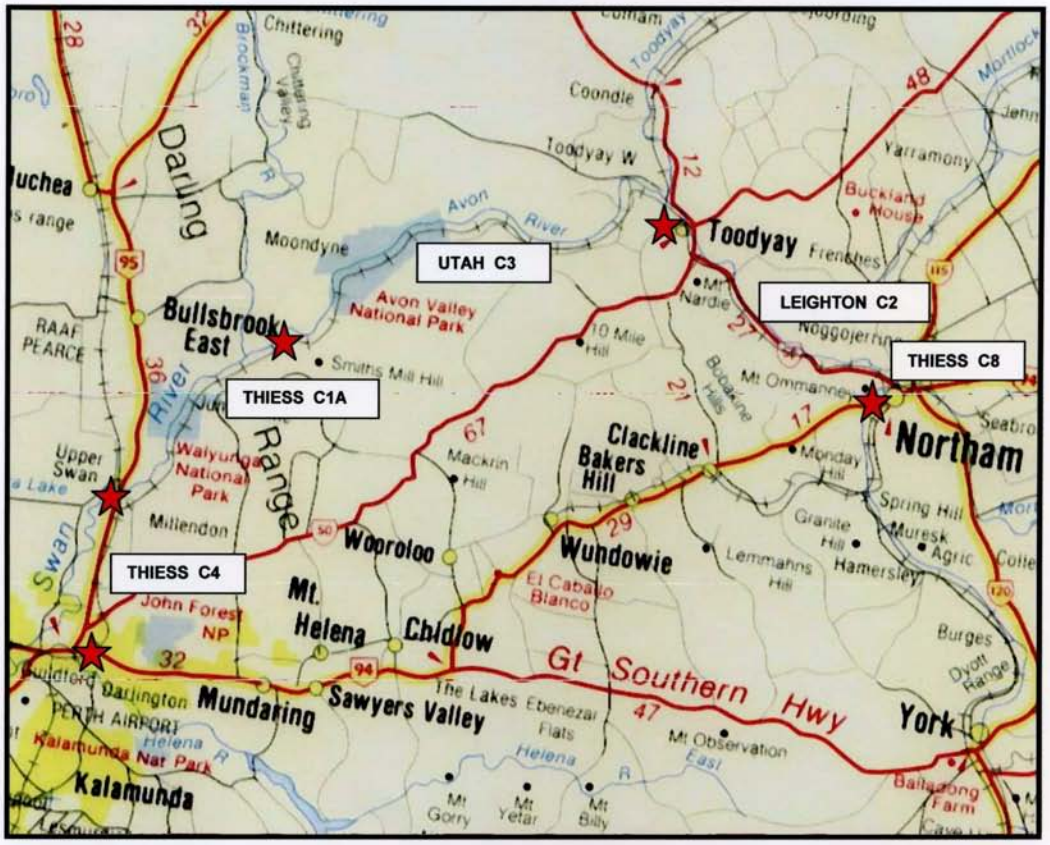
Two bridges across the Avon River were eliminated from the original Contract C1

The two rock cuttings proposed by Thiess were accepted by the WAGR and incorporated in Contract C1A.

A large rock cutting through Windmill hill, east of Toodyay, eliminated another two bridges originally included in Contract C2

STANDARD GAUGE RAILWAY PROJECT

AVON VALLEY SECTION



The Western Australian Government Railways (WAGR) Standard Gauge Project from Kwinana, to Kalgoorlie and Esperance commenced in 1962 and was completed in 1975.

The Avon Valley Section from Midland to Northam was the most challenging and expensive. It involved the largest earth and rock cuttings ever excavated for a civil project in WA before. (1962 – 1964)

Contract C1A : Millendon to Smiths Mill Hill - Thiess/Perron Bros.

Contract C2 : Toodyay to Northam - Leighton Contractors

Contract C3 : Smiths Mill Hill to Toodyay - Utah Construction

Contract C4 : Midland to Millendon - Thiess/Perron Bros

Contracts C5, C6 & C7 : Marshalling yards and bridges in Northam - Leighton, Clough and others.

Track Laying & signals : WAGR

Contracts C8, C9, & C10 : Northam to Kalgoorlie - Thiess Bros. (1964 – 1968)

6.3 Northam to Merredin and Southern Cross

From Northam to Merredin the ruling gradient of 1 in 150 was readily obtainable within the existing NG reserve with a limited number of deviations. To keep the NG line in operation, at two locations it was passed over the new SG railway on temporary fly-over structures. Some substantial service diversions were necessary over this section, principally to the Great Eastern Highway, the Goldfields Water Supply and the East-West Telephone Trunk route. The Goldfields Water Supply pipeline bridged over the SG line at two sites and passed under the railway at another two.

A new marshalling yard for both gauges was provided on the western side of the town of Merredin and the three existing NG branch lines, from Nungarin (to the north) and Bruce Rock and Narembeen (to the south), were connected into the yard. Co-operative Bulk Handling constructed a grain transfer and storage facility of 12,000 cubic metres capacity within the yard and, on 11 November 1966, the first SG grain train ran from Merredin through to Leighton Yard at Fremantle.

The existing NG railway between Merredin and Southern Cross was crossed by a series of north-south ridges making the attainment of a 1 in 150 ruling grade within the NG reserve difficult and costly. Deviation from the existing reserve for almost the total distance was therefore required.

6.4 Southern Cross to Kalgoorlie via Koolyanobbing

The route from Southern Cross to Koolyanobbing follows a series of lakes but the design of waterways in this length and for the next 80 km presented problems due to the lack of formal records of watercourse behaviour and the existence of very large intermittent catchments which flooded on rare occasions only. Investigation of all major catchments was made by helicopter and of the smaller ones by wheeled vehicles. In areas subject to sheet flow bunds and cut-off drains were provided to protect the toes of embankments. Culverts were sized to allow for the high rainfall intensities associated with remnant cyclones from the north-west passing through this area. Much of the route east of Koolyanobbing passes through salmon gum and morell woodland which has fine silty 'bull-dust' soil. Embankments of this material were constructed satisfactorily although for adequate compaction the soil requires a high optimum moisture content averaging 20%. Embankments of bull-dust soils were protected with layers of compacted gravel (100 mm for topping and 75 mm for sheeting), (See also 9.3 d)

6.5 Metropolitan Area

The variations which were made to the original 1961 Agreement to route the standard gauge railway through the Metropolitan Area were incorporated in the revised schedules to the Agreement made in November 1963 and are described in Section 5.6 of this document. The railway network in the Metropolitan Area after the completion of the SGR project is illustrated in Figure 1 which also shows the sections of track which were laid in SG, NG and dual gauge.

As the SG route enters the built-up areas it passes round Midland in a clockwise direction and divides at West Midland Junction into two dual gauge lines. One follows the existing NG route to a new passenger terminal at East Perth. The other branch running south from West Midland passes the Forrestfield – Kewdale railway complex. This route crosses the south-western railway at Kenwick and skirts round the southern edge of the built-up area to Cockburn Junction where the SG route divides. South of Cockburn Junction a dual gauge line continues to Kwinana. From Cockburn the other SG line continues westwards to the coast at Robb Jetty and then north into Fremantle.

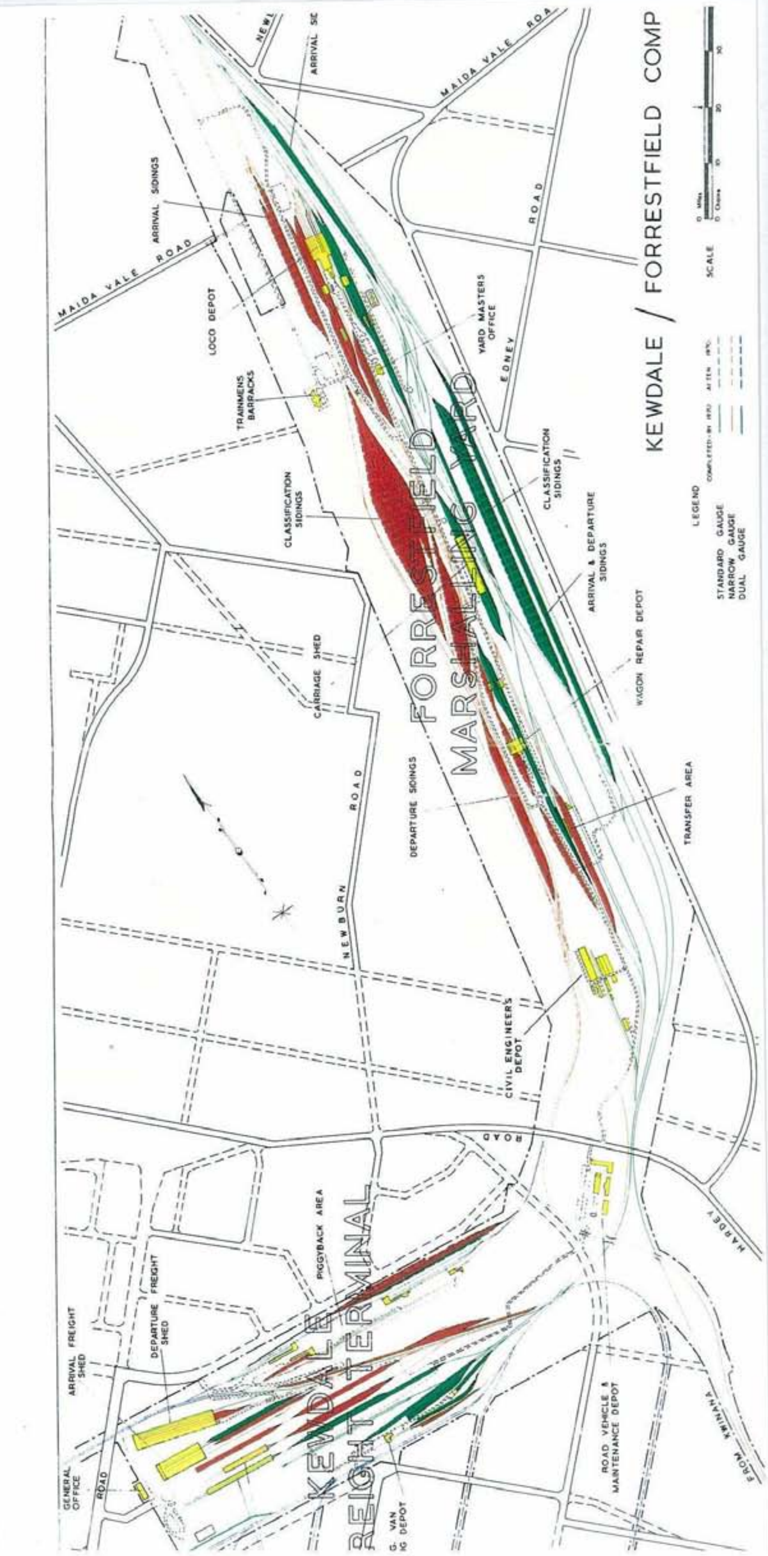
South of West Midland, apart from the urban corridor at Kenwick, the SG route to Kwinana and Robb Jetty in the 1960s was still in rural use. The early and mid-1960s were a crucial 'window of opportunity' for the planning of the metropolitan area. The main constraints for the location of the marshalling yard were main drainage schemes and reserves for future highways. Around Cockburn and further south constraints included Jandakot airport, the cement works and a paper mill.

The Forrestfield marshalling yards were originally orientated east-west and sited at the eastern end of Kewdale freight terminal but the length of sidings required for the anticipated SG traffic could not be accommodated at Kewdale so the longer Forrestfield site was adopted. The north-south orientation of the yard, in line with the flow of traffic, allowed for its more efficient working. The new diesel locomotive depot was located at the north end of the Forrestfield site together with the installations needed to service the requirements of SG freight and passenger rolling stock such as a carriage washing plant and an industrial liquid waste treatment plant. Refer to diagram on page 17 for the layout of the Forrestfield and Kewdale yards.

Wheat is the most important commodity carried by the railways in the south-west and handled through the SGR. Grain movements are largely controlled by Cooperative Bulk Handling (CBH) whose most important export terminal was on the North Quay at Fremantle. In 1967 the terminal was altered to receive only the new large capacity bottom-discharge wheat wagons, 140 of which were built as part of the SG Project. Grain from NG lines was directed to transfer and storage terminals in Merredin and Avon yards from which it was conveyed to Fremantle by fast unit trains with up to 2 500 tonnes payloads on shuttle services. The wheat trains went up the coast from Cockburn Junction via Robb Jetty, around the west end of Fremantle and over Fremantle bridge for rapid discharge at the North Quay Terminal.

In 1976 CBH replaced its grain terminal on North Quay with a very large new terminal at Kwinana which it describes as 'the largest and most modern in the world' and which has access to deep-draft moorings. The new location of the terminal was an important consequence of the long term planning for the Metropolitan Area and was made possible by the direct rail service to Kwinana provided under the SGR project.

KEWDALE-FORRESTFIELD COMPLEX



7 Standards and technical information

7.1 SG Route Distances

Kalgoorlie to Koolyanobbing	126 miles	[203 km]
Kolyanobbing to Southern Cross	33	[53]
Southern Cross to Northam	184	[296]
Northam to Midland	65	[106]
Midland to Kewdale	8	[13]
Kewdale to Cockburn Junction	16	[26]
Cockburn Junction to Kwinana	8	[13]
Cockburn Junc. to North Fremantle	8	[13]
Midland to East Perth	10	[16]

7.2 Geometry, Speeds and Loadings

Ruling Grades

Kalgoorlie to Northam	1 in 150
Northam to Cockburn Junction and Kwinana	1 in 200
Cockburn Junc. to North Fremantle	1 in 150

Maximum Curvature

Normal minimum radius	40 chains [800 m] spd restr. 60 ml/h [90 km/h]
Avon Valley minimum radius	20 chains [400 m] spd restr. 45 ml/h [70 km/h]
Sharpest bend, radius	10 chains [200 m] spd restr. 30 ml/h [50 km/h]
(Cliff Str., Fremantle)	

Clearances

A width of 12 feet [3.7 m] was provided at a height of 20 feet [6.1 m] above rail level to accommodate the highest pig-a-back and out-of-gauge traffic.

Maximum Speeds

Passenger trains	70 ml/h	[110 km/h]
Rail cars	80 ml/h	[130 km/h]
Freight trains	50 ml/h	[80 km/h]

Axle Loadings

Bridge design loading Coopers E.50
General rolling stock: maximum axle load 20 tons
Iron ore and grain wagons: axle load 23.5 tons spd restr. 45 ml/h [70 km/h]

7.3 Earthworks

Formation widths are as follows:

	Single Track	Double Track
Embankment	20 ft [6.1 m]	33 ft [10.0 m]
Cutting	22 ft [6.7 m]	35 ft [10.7 m]

The general compaction standard for embankments was 92% B.S. Standard Compaction (Modified ASSHO). Generally all formations were topped with approximately 6 in (150 mm) of selected material compacted to 97% B.S.

7.4 Trackwork

Rail

The Agreement specified 94 lb per yd [47 kg per m] A.S. rail and conventional Australian fastenings for the main line.
Main line rail was flash-butt welded into 360 ft [110 m] lengths in the WAGR flash-butt welding depot at Midland. Rails were field welded into 1,440 ft [439 m] lengths by the 'Quick Thermit' process.

Sleepers

On SG track 8 ft x 9 in x 4½ in [2 440 x 230 x 115 mm] indigenous hard wood timber sleepers laid at 2,640 per mile [1,640 per km] were used. On dual gauge track 5 in [127 mm] deep sleepers were used to provide additional stiffness.

Ballast

2,900 cubic yards per mile [1,380m³per km] of crushed rock ballast was used, representing approximately 9in [230 mm] under sleepers. The specification called for 1½ in x ⅜ in [38 mm x 10mm] grading with a Los Angeles Abrasion of less than 30% west of Northam and 40% east of Northam.

7.5 Bridgeworks

Prestressed concrete was adopted as the standard construction for bridge superstructures on the project and where possible bridges were designed in three standard spans, 100 ft, 60 ft and 35-38 ft (30 m, 18 m and 11-12 m).
The standard 100 ft span bridge consisted of a torsionally rigid prestressed box girder for each track. On double track the spans were structurally independent. The box girders were designed for either precasting or cast insitu techniques and were stressed by high tensile steel cables.
The design of the standard 60 ft span was similar except that the two beams forming the girder were not connected at the bottom to form a box, diaphragms being provided in lieu.
For minor bridges a standard 35-38 ft span bridge was designed consisting of precast pretensioned inverted T units forming a soffit braced by a cast insitu concrete deck.

Waterway Bridges

River	Location	Contract	Spans	No. of Tracks
Wooroloo Brook	Avon Valley	C1	2x 100ft	2
Avon	Northam Weir	C2	6x 100ft	2
Jimperding Creek	Avon Valley	C3	1x 100ft	2
Avon	Northam	C5	6x 100ft	2
Avon	Toodyay	C6	6x 100ft	1
Mortlock	Northam	C8	4x 60ft	1
Helena	West Midland	C21	5x 60ft	4
Canning	Kenwick	C21	5x 60ft	2
Swan	Guildford	C27	6x 100ft	3

Other Bridges

The Great Eastern Highway bridge at Northam (6 x100 ft) and 12 other bridges with spans of less than 50 ft. were included in the SGRP.

Temporary over-bridges were built to carry the NG line to Kalgoorlie over the new SG line at six locations between Northam and Southern Cross. These were used when both NG and SG services were operating between Northam and Southern Cross. The over-bridges were removed when the NG service was discontinued and the line lifted.

Drainage Culverts

In general, minor culverts were constructed of single or multiple reinforced concrete pipes up to 42 in [1.1 m] in diameter. Larger culverts are single or multiple reinforced concrete box culverts of 6 ft [1.83 m] standard width which were fully cast insitu or were cast insitu with precast deck slabs.

7.6 Signalling

The signalling for the SGR Project was designed by the WAGR Signals and Telegraph Engineering (S&TE) Department which let 7 contracts for the work and supervised its installation including pole lines and signalling in the major yards and at level crossings. The basic form of signalling is 2 and 3 aspect colour lights of the searchlight type applied as follows:

For the main line from Kwinana and Fremantle to KoolyanobbingCentralised Traffic Control with colour lights signals and motorised points;

For the main line from Koolyanobbing to Kalgoorlie automatic colour light signalling and manually operated points;

In major yards and at junction stations panel rolled power operated arrival and departure signalling.

7.7 Major Contracts

Major Civil Engineering Works Ew – Earthworks Tk – Tracklaying

Contract	ContractContent	Contract Period	Contractor	Estimated cost (x $1000)
C1A	Avon Valley: Middle Swan-Jimperkine Ew. WoorolooBk bridge	1962-64	Thiess/Perron	2430
C2	Avon Valley: W. Toodyay-Northam. Ew Avon R. bridges (5)	1962-64	Leighton`	3000
C3	Avon Valley: Jimperkine-W.Toodyay. Ew. Jimperding Creek bridge.	1963-64	Utah	2560
C4	Swan/Avon Valley. E.Midland-Middle Swan. Ew	1964-65	Thiess	220
C5	Avon Valley: Northam Yard-Northam Station Ew, W. Northam bridges (3)	1965-66	Utah	1500
C6	Miling branch connection, Avon R. bridge (6 x100ft)	1963-64	Utah	340
C7	Midland to Merredin& country station yards: Tk	1964 Utah	5380	
C8	Northam-MerredinEw, Mortlock R. bridge (3x60ft)	1964-65	Thiess	3500
C9	Merredin-KoolyanobbingEw, Tk; Merredin Yard, Yerbillon bridge (3 x35ft)	1965-66	Thiess	
C10	Koolyanobbing-KalgoorlieEw, Tk Kalgoorlie Yard Ew	1966-68	Thiess	8980

C14	West Kalgoorlie Yard Ew; services & buildings	1969-70	Thiess	
C21	Kenwick-West Midland Ew; bridges:Helena R.(2), Canning R., Kenwick, Kewdale (2).	1964-65	Christiani& Nielsen	1712
C22	W. Midland-Robb Jetty Tk (SG & NG); Spearwood bridge Ew	1965-66	Clementsons	
C25	Kewdale Terminal Ew, Tk; main line deviation	1968-69	Bell Bros	
C26	Cockburn Junc.-Kwinana; Kwinana Yard Ew, Tk	1966-67	Clementsons	
C63	Forrestfield Yard sorting sidings Ew	1970	Caratti	

Major Building Works

	Number of separate contracts
Kewdale Freight Terminal	13
ForrestfieldMarshalling Yard	13
Robb Jetty Freight Terminal, Leighton Yard, North Fremantle, Kwinana Yard	4
East Perth SG Passenger Terminal, Rail Car Depot	4
Avon Yard, Merredin Yard, W.Kalgoorlie Yard, 3 trainmen's barracks, 15 country stations	14

In the design of building works Maunsell & Partners was assisted by Forbes & Fitzhardinge (architects), McLellan & Partners (electrical engineers), W.E.Bassett & Partners (mechanical engineers) and Rawlinson Roberts (quantity surveyors).
A total of sixty-five major contracts were required to complete the civil and building works for the Standard Gauge Railway Project.
Appendix B contains a list of the major building contracts and the builder associated with each.

7.8 Major Construction Material Quantities

The mainline construction involved approximately 16,000,000 cubic metres of earthworks. In the Avon Valley section alone there were approximately 2,675,000 cubic metres of earthworks of which approximately 1,530,000 cubic metres were rock excavation.

There were approximately 1,500,000 tones of crushed rock ballast; 128,000 tonnes of steel in the rails and fasteners and 1,950,000 sleepers used in tracklaying.

7.9 Rolling Stock Purchased

Diesel Electric Locomotives

3300 HP mainline locos (English Electric Class L)	23
1950 HP mainline locos (English Electric Class K)	10
950 HP transfer locos (English Electric Class H)	5
600 HP shunting locos (English Electric Class J)	5

45 Ballast hoppers, 35 flat top wagons and 5 brake vans were purchased for construction.
Wagons for operations: 18 different types purchased, a total number of 1224, including 155 iron ore wagons and 12 refrigeration vans. Many of the components were made by local firms, Bradford Kendall, Hadfields and Tomlinsons. Coaching stock purchased comprised 60 units, including 8 rail cars, 16 brake vans and 24 coaches.

8 Project Management

8.1 Governance

Project initiation and subsequent governance was led at the policy level by:

The Premier of Western Australia- David (later Sir David) Brand

The Western Australian Minister for Railways – Charles (later Sir Charles) Court

The WAGR Commissioner – Cyril Wayne, then John Horrigan (1967) and

James Pascoe (1971)

Technical Adviser – Cedric Stewart (former Chief Civil Engineer)

8.2 Planning Coordination

Project definition, policy scope and intergovernmental negotiation were managed by:

The Coordinator of SG Planning – Charles Gates, then Edward Blackwood (1965)

Standard Gauge Finance Officer – Ronald Martin, then Cyrus Menagh

Standard Gauge Planning Engineer – Lawrence Fullerton

8.3 WAGR Executive Management

The heads of WAGR branches were responsible for the standards applicable to their disciplines and within their designated areas of operation:

Chief Civil Engineer – John Horrigan, then Howard Williams (1965), then

Ian McCullough (1966)

Chief Mechanical Engineer – Sidney Griffiths, then William Blakeney-Britter (1966)

Chief Traffic Manager – James Pascoe, then Joseph Kinsella (1971)

Signal & Telecommunications Engineer – Donald Curtis

8.4 Project Direction

WAGR officers responsible for the implementation of the project including the direction of consultants and WAGR construction staff, and the programming and supply of materials were:

Assistant Chief Civil Engineer – Ian McCullough, then Mervyn Abbott (1966)

Construction Engineer – Mervyn Abbott, then Robert Dean (1966)

Liaison Engineer – John Hoare

8.5 Project Engineering Consultants

Prior to the initiation of the Standard Gauge Railway Project the London-based engineering consultancy, G. Maunsell and Partners, had carried out major assignments for the Western Australian Government, notably the Narrows bridge and Fremantle railway bridge. The Australian branch of the company, Maunsell and Partners, under senior partner, Miles Birkett, was appointed engineering consultant for the project. The company was responsible for the design and supervision of the major civil works, railway track construction (clear of operating lines) and new buildings and services required for the project. A Perth office was established for the project led by the following:

Resident director – Paul Andrew, and then Patrick Sands (1964)

Senior planning engineers – Robert Meager, Dennis Riley

Senior structural engineer – James Leslie

Contracts manager – Alan Wilkinson

Senior resident engineer – Hugh Alexander

8.6 Civil Works Contractors

Thiess Bros Pty Ltd

Thiess Bros began as a roads contractor in Queensland in the 1930s.In May 1958 the firm won national acclaim when it became the first Australian company to be awarded a major contact on the Snowy Mountains Hydro-Electric Scheme. It subsequently became the contractor which did the most work on the scheme, successfully completing seven major contracts valued at more than $98 million.

In 1962 Thiess formed an association with Western Australian company Perron Bros Pty Ltd which successfully tendered for SGR contract C1A, comprising the earth and bridge works in the lower Avon Valley from Middle Swan to Jimperkine Hill. Subsequently, in Thiess Bros' name only, the company completed five other contracts which included most of the earthworks, culverts and bridges between Northam and Kalgoorlie and the track laying between Merredin and Kalgoorlie The C10 contract, for the earthworks and track laying between Koolyanobbing and Kalgoorlie, at $8,980,000, was the largest single construction contract awarded on the project. The company was subsequently taken over by Leighton in 1983. Thiess state managers during the SGR contacts were Dick Sukias and Roy Carroll. Bob Elliot was Project Manager for the C1A contract and Bruce Puncher Project Manager for the C8 contract.

Christiani and Nielsen (Australia) Ltd

Christiani and Nielsen (Australia) was a subsidiary of an international Danish civil engineering company which was founded in Copenhagen in 1904. In 1956 it accepted an invitation from Perth construction company J.O.Clough and Son Pty Ltd to jointly submit a tender for Perth's Narrows Bridge. The tender was successful and the C&N Clough Joint Venture constructed the bridge in 1957-1959 and subsequently built the Ord River Diversion Dam in 1961–1963. Christiani and

Nielsen (Australia) constructed SGR bridge works during 1963-1965 in the Northam and Toodyay areas as a subcontractor to Utah which was the main contractor for the C5 and C6 contracts. Christiani and Nielsen (Australia) also carried out the C21 contract for bridges and earthworks between Kenwick and West Midland in 1964-1965. Poul Erik Rasmussen was Project Engineer for the Northam bridges and Tony Quinlan Project Engineer for the Toodyay bridge of the C5 and C6 contracts.

Utah Construction and Engineering Pty Ltd The Utah Construction Company was founded in Utah, USA, in 1900 and became experienced in railway and dam construction in the USA and Mexico. After World War 2 it also moved into mining and changed its name to Utah Construction and Mining Company which was the company that came to Australia to participate in the Snowy Mountains Hydro-Electric Scheme. Over ten years, in joint ventures, it built three large SMHEC dams and 55 km of tunnels. Utah was also part of a consortium, Mount Goldsworthy Mining Associates, which in 1962-1966 developed an iron ore mine at Mount Goldsworthy, 100 km east of Port Hedland. On the SGR Utah carried out C3, (the earthworks in the middle Avon Valley from Jimperkine to West Toodyay and the Jimperding Creek bridge),and also C5 and C6 (earthworks and bridges in the Northam area) and the C7 contract which was for tracklaying along 360 km of the SG route between Midland and Merredin.

Leighton Contractors Ltd

Leighton Pty Ltd was founded as a private company in Australia in 1950 by Englishman Stanley Leighton. It became an Australian public company in 1962 and has since grown to be Australia's largest construction company. It carried out SGR contract C2 which comprised earthworks and bridges in the upper Avon Valley from West Toodyay to Northam, including the Windmill Hill cutting near Toodyay, the biggest cutting in the Southern Hemisphere. Bruce Puncher was Project Manager for the contact.

E.S. Clementson Pty Ltd

Clementson was an earthmoving company from New South Wales which in 1959 -1961 built the Bendora Dam near Canberra for the National Capital Development Commission. In 1966-1967 it carried out SGR contract C26 for the earthworks and track laying between Kwinana and Cockburn Junction.

Franco Railroad Contractors (Australia) Pty Ltd

The majority of the track laying on the SGR was carried out by Franco in subcontract relationships with Thiess, Leighton and Utah. Significantly the nucleus of their track laying team was a highly skilled and productive team of Thursday Islanders who were brought to Western Australia by Franco. Many of them stayed on to work on other railway projects in Western Australia.

9 Assessment of Engineering Heritage Significance

9.1 Historical Significance

The completion of the Western Australian Standard Gauge Railway (SGR) Project was of historic significance because it heralded the elimination of the breaks in railway gauge between the railways of different states which had hampered trade across the nation ever since the first meetings of railways of different colonies in the 1880s. The completion of a SG railway across the nation led to improvements in travel times and reductions in freight costs and enabled the railways for the first time to provide an effective east-west 'land bridge' for freight across the nation.

The arrival of the SG led to important changes in the planning and development of the Perth metropolitan area. The move to replace or upgrade outdated NG facilities and to provide new SG ones coincided with the preparation of the town planning scheme for the Metropolitan Region following the Stephenson-Hepburn planning report. The consequent coordinated planning re-orientated the direction of urban development from the original east-west alignment the extension of which was confined by the foothills of the Darling Range to a new north-south alignment which allowed more extensive urban and industrial expansion.

The main WAGR combined freight terminal and marshalling yard was moved from a cramped site in central Perth to more extensive 'green fields' sites adjoining each other at Kewdale and Forrestfield on the south-east edge of the built-up area on the SG line to Kwinana. The closure of Perth Yard was the first step in the redevelopment of central Perth. The major freight forwarding companies relocated their sidings and road depots in Kewdale which developed as the main freight handling centre for the metropolitan area. At Forrestfield modern NG and SG marshalling yards replaced the Perth yard and also two other inner city marshalling yards. The diesel locomotive depot was also built at Forrestfield while Bunbury, near the Collie coalfields replaced East Perth as the main steam locomotive depot.

The direct SG line to Kwinana to serve the BHP developments attracted other major industries to Kwinana such as the nickel refinery and the fertiliser works and also led to the development of Cockburn Sound by Fremantle Harbour Trust as its outer harbour for the handling of bulk materials, in particular Cooperative Bulk Handling's location of its bulk grain terminal. The railway link and the proximity of the metropolitan area also led to the decision of the Australian Government to site its major Indian Ocean naval base in Cockburn Sound.

In the Eastern Goldfields the completion of the SG main line prompted the WAGR to also convert to SG the two isolated NG lines from the main line, to Leonora to the north and to Esperance on the south coast which enabled mineral traffic to be railed for export by block trains through either Fremantle or Esperance from as far inland as Wiluna and Laverton.

The economic advantages to Western Australia of the Standard Gauge Railway Project were evident soon after the completion of the standard gauge railway across the nation. In one year which ended in June 1974, four years after the SG was open, interstate freight carried by rail went up by 35 per cent. Ten years later the amount carried by rail was six times what it had been in 1974. By

September 2011 the interstate standard gauge railway carries in excess of 80% of the land freight between Western Australia and the Eastern states.

9.2 Social Significance

The completion of the Western Australian Standard Gauge Railway Project coming as it did at the same time as the first modern Western Australian minerals boom symbolised for many Australians the 'coming of age' of Western Australia in the Australian Federation. For the Western Australian Government Railways Commission which had suffered severe financial malnutrition during the 1930s and 1940s and had been overworked without respite during the war years, the SGRP came as a once in a lifetime opportunity to modernise and reorganise railway infrastructure particularly in the metropolitan area and to prepare the Commission for the commercialisation of its operations which appeared to be approaching.

9.3 Technological Achievements and Contributions to Engineering Practice

The Standard Gauge Railway Project encompassed a wide range of railway engineering disciplines each of which in its own field contained 'state of the art' engineering which varied or extended existing best practices.

a) ***Cuttings in Avon valley rock formations***

Deep weathering of the Darling Range granites and sheet joints parallel to the surface made it necessary to vary pre-splitting and shaping blasting techniques used in more homogeneous rock. Cutting cross sections had to be varied with the local geology. For instance, berms in cuttings had to be repositioned to avoid sheet joints and drainage at the bottom of cuts had to be redesigned to avoid cutting into highly stressed rock. Considerable variations in the batter slopes was required. The most difficult case was at Windmill Hill cutting, the deepest cutting on the project, which on the higher side was designed as four lifts of 10m with batters at 55º. However the discovery of a soft 18m long deeply weathered schist layer at the base of the cutting made it necessary to make a laid back re-entrant to the cutting with a lower batter at 30º and an upper one at 35º with the whole re-entrant later protected with stone pitching.

b) ***Track laying techniques***

Main line rail was flash-butt welded into 110 m [360 ft] lengths in the WAGR flash-butt welding depot at Midland. These long lengths had to be laid at a mean average temperature of about 32 degrees Celsius [90°F]. In summer rail was sprayed with water to lower its temperature to 27° C [81º F] which allowed the temperature to rise to 32º C by the time it was laid. In winter the rail was heated with LP gas burners pushed backwards and forwards on a trolley.

The first tracklaying started from Upper Swan (one of the 3 material depots on the project) and progressed eastwards. Rail was taken by train to the rail head. It was then pulled forward off the construction rake by a straddle crane onto the previously positioned sleepers. In the Avon Valley one track was laid to Northam and the other back to Upper Swan. The second track was laid in a

novel way. The rail train ran on the track already laid and swung the two rails off the train onto the other track.

After the rails had been fixed in position with ballast they were field welded into 439 m [1,440 ft] lengths by the 'Quick Thermit' process.

The contractor who did the tracklaying in the Metropolitan Area had a different method of operating. The track was prefabricated into panels 27 m long by spiking the rail onto the sleepers. The panels were stacked two high and fixed with flanged wheels and were towed to the railhead by a tractor also fitted with flanged wheels. At the railhead the flanged wheels were replaced with rubber tyred wheels and the tractor towed each of the panels into position.

c) ***Standard bridge types***

In the early SGR contracts companies could submit tenders for bridges with either prestressed concrete or steel superstructures. Although capital costs for structures in the two materials varied little, the lesser maintenance cost of concrete structures lead to the selection of prestressed concrete as the standard for the project. Only the Guildford bridge over the Swan River was built in steel to match an existing bridge.

Bridges were designed in three standard spans, 30 m, 18 m and 11-12 m. Major bridges had all spans as either 30 m or 18 m (see 7.5). The 30 m span bridge had a box girder for each track which could be either precast or cast insitu. Both methods were used by different contractors. The girders were post-tensioned. The 18 m bridge was similar except that its two beams forming the girder were not connected as a box but had stiffening diaphragms instead. The two bridge designs proved to be economical ones in terms of cost per unit length for the two spans.

d) ***Railway embankments in 'bull-dust' soils***

Much of the SG route from Koolyanobbing to Kalgoorlie passes through a low rainfall area containing salmon gum and morrel woodland which has distinctive fine-grained silty soils, commonly known as 'bull-dust'. These soils require a high moisture content, of up to 20%, to achieve adequate compaction. Laboratory and field trials were carried out into the compaction of 'bull-dust' embankments, their protection against erosion and what parts of a 'bull-dust' borrow pit would produce the most suitable fill material. Consequently, to prevent erosion bull-dust embankments were topped and sheeted with gravel, batters were flattened to 1 in 4 and high fills were provided with berms.

9.4 Rarity and Environmental Value

The Indian Pacific passenger service on the Standard Gauge Railway across Australia is one of the very few railway services in the world which crosses a whole continent from east to west and it is the only one on which passengers can travel the full distance between sea-board cities without changing trains. It provides passengers with a unique range of landscape experiences, in Western Australia for example, such as those along the rugged Avon Valley and the woodlands of the Eastern Goldfields between Koolyanobbing and Kalgoorlie which cannot be experienced to the same extent when traveling by road or by air.

9.5 Integrity and Authenticity

Nearly 40 years have passed since the major works of the Western Australian Standard Gauge Railway Project were completed. Some elements of the project's infrastructure have become redundant with the changing commercial requirements of the railway industry but the key elements of the Scheme are now such essential parts of the State's infrastructure that it requires a considerable effort of research to appreciate the changes that took place in the State's infrastructure during the ten years of the Western Australian Standard Gauge Railway Project.

10. Eminent persons associated with the Project

Cyril G. C. Wayne

Cyril Wayne was Western Australian Railway Commissioner from 1959 to 1967, years which included those leading up to the start of the Standard Gauge Railway Project and its critical early years. The 1950s had been disappointing years for the WAGR and it was Wayne who was largely instrumental in raising the morale of WAGR personnel to the extent that they could successfully manage such a major undertaking as the Standard Gauge Project.

Wayne was born in the United Kingdom and studied for two years at the London School of Economics after which he became a trainee traffic manager with the London and North Eastern Railway. In 1925, while still a student, he visited the United States and worked for several months at the Chicago, Milwaukee and St Paul Railroad Company. From 1926 to 1928 he worked for the Shangai to Nanking Railway but because of the civil war in China he had to return to the UK. In 1929 he moved to Argentina to join the traffic branch of the Buenos Aires Western Railway for which he worked for twenty years, rising to the position of Assistant Chief Traffic Manager. After the Peronista regime came to power and nationalised the railways he moved to Australia to join Tasmanian Railways for which he was General Manager from 1952.

The newly elected Brand Liberal–Country Party Government appointed Cyril Wayne Western Australian Commissioner of Railways in 1959. The WAGR was then badly in need of rehabilitation; annual railway deficits were increasing; backlogs in trackwork and locomotive maintenance had built up during the war causing concerns about safety; the service had a poor public image after two critical Royal Commissions since the war; and the new three-man Railway Commission had broken down ignominiously in 1957. Wayne tackled reforms with energy and enthusiasm. At the local level a three man inter-departmental, review committee travelled the railway network investigating and improving matters such as wagon utilisation, routing and time-tabling and for the first time commercial representatives were appointed to sell the railways' services to business organisations. Services were extended to serve new ventures in the mining of bauxite, iron and salt and the bulk handling of wheat was improved to handle more efficiently two record harvests.

When BHP agreed with the State Government to develop a steel industry at Kwinana, provided a SG railway was built from Kwinana to Koolyanobbing and Kalgoorlie by the end of 1968, Wayne travelled to Canberra with Premier Brand and the Railways Minister Court to seek finance not only for the railway itself but for all the infrastructure necessary to support SG traffic and to continue handling NG traffic or to transfer it to SG. Wayne and Court later had further negotiations with the Commonwealth over the financing of acceptable variations to the agreement.

In 1966 Wayne undertook for the State Government a comprehensive review of transport policy in which he recommended greater coordination of bus and rail services which was to become a major feature of future urban passenger transport. In 1967 he had to retire for reasons of health. In the eight years he had been Commissioner he had presided over a revolution in the operations of the WAGR and in how it was perceived by the public.

Sir David Brand (1912 -1979)

David Brand was the Western Australian Premier throughout almost all of the Standard Gauge Railway Project. He was born in Dongara, Western Australia, and joined the AIF in 1939. He was wounded while serving in Greece in 1941. After his discharge from active service in 1942 he served as a sergeant in the Volunteer Defence Corps until the end of the war in 1945.

He joined the Liberal Party in 1944 and won the State seat of Greenough in a 1945 by-election. He held the seat until he retired thirty years later in 1975.

In April 1950 he became Minister for Works, Water Supply and Housing in the McLarty Liberal – Country Party Coalition Government. After the defeat of the coalition in 1953 he became deputy leader of the Opposition and, on McLarty's retirement, Opposition Leader from March 1957. When the Coalition regained power in 1959 he became Premier, Treasurer and Minister for Tourism, positions he held until the election in March 1971. His eleven years, eleven months and one day as Premier exceeded by more than one year Sir John Forrest's record. He was knighted in 1969.

David Brand presided over one of the most exciting periods of development in Western Australia's history. His partnership with the then Minister for Railways and Industrial Development, Charles Court, proved exceptionally successful. They were both present at a ceremony in 1962 when an explosive charge was fired in the Avon Valley to signify commencement of the earthworks for the first stage of the Standard Gauge Railway Project.

After his Government was narrowly defeated at the polls in 1971, Sir David stepped down as Leader of the Opposition in 1972. He retired from Parliament on 21 August 1975 and died on 15 April 1979.

Sir Charles Walter Michael Court (1911 - 2007)

Charles Court was the Minister for Railways in the Brand Government and took a leading role in negotiating the 1961 Railway Standardisation Agreement with the Commonwealth Governmenrt. He was born in England at Crawley in Sussex and came to Western Australia with his parents as an infant. He was educated at Perth Boys' School and Perth Technical College. He qualified as a chartered accountant in 1933 and, in 1938, became a foundation partner of Hendry, Rae and Court, accountants. He served in the Australian Army in World War 2, enlisting as a private in 1940 and rising to the rank of Lt-Colonel by September 1945.

He entered the Western Australian State Parliament as Liberal MLA for Nedlands in 1953 and held the seat until he retired in 1982. When the Liberal Government under David Brand was elected in 1959, Charles Court became Minister for Railways, Minister for the North-West and also Minister for Industrial Development. During his tenure he had an important influence on the mineral and energy developments in the North-West and on other rural and mineral developments. He coordinated and was actively involved in the first stages of Ord River farm development and the establishment of the town of Kununurra, following the joint funding agreement between the Commonwealth and State Governments to establish an irrigation scheme in the Kimberley region of WA.

While he was Minister for Railways from 1959 to 1967 the Standard Gauge Railway Project was initiated and substantially completed. In 1963 he took a very active part in the Ministerial negotiations between the Western Australian and Commonwealth Governments over variations to the 1961 SGR Agreement (see

para. 5.6 above) and over the appointment of consultants to prepare a Master Plan for the complete Project (see 5.7).

During the Tonkin Labor Government (1971-1974) Court became Leader of the Opposition and subsequently served as Liberal Premier from 1974 to 1982. In 1972 he was knighted for his services to state and national development.

John Bryan Horrigan (1906-1984)

Jack Horrigan was Western Australian Railway Commissioner during the four year period of peak expenditure on the Standard Gauge Railway Project from 1967 to 1971. He was educated at Perth Modern School and the University of Western Australia where he studied engineering.

He joined the Railway Construction Branch of the Public Works Department of Western Australia, as a cadet, in 1925 and became a probationary engineer in the department on graduation from the university in 1930. When the Railway Construction Branch was incorporated into the Western Australian Government Railways (WAGR) in 1931,he joined the Way and Works Branch of the WAGR. In 1932 he visited the United Kingdom where he worked for the Middlesex County Council in West London.

On his return to Australia, Horrigan rejoined the WAGR and, in 1934-35, was resident engineer on the construction of the foundations of a major extension to the East Perth Power Station which provided power to the whole of the Perth metropolitan area. The power station was operated by the Western Australian Government Electricity Service which was then a branch of the WAGR.

In 1948 Horrigan was made WAGR District Engineer at Narrogin and, in 1949, he was appointed to a three member Planning Board to investigate the long-term development requirements of the WAGR. After Cyril Wayne became Commissioner in 1959, Horrigan became Assistant Chief Civil Engineer under Chief Civil Engineer Cedric Stewart, and in 1962, the year in which the Standard Gauge Railway Project officially commenced, he succeeded Stewart as Chief Civil Engineer.

In 1965 he became Technical Adviser to Commissioner Wayne and, while Wayne was undertaking a review of transport policy for the Government in 1966 and 1967, Horrigan was appointed Deputy Commissioner. When Commissioner Wayne retired because of ill-health, in 1967, Horrigan was ready to step into his shoes. When, four years later, Horrigan retired himself, the Standard Gauge Railway Project was almost complete and major changes to the WAGR had been made under his stewardship, not only in the metropolitan area but throughout the system.

Patrick George Sands

Patrick Sands was born in England at Burnham in Buckinghamshire. He was educated at Caterham School, Surrey, and Imperial College, London, where he studied engineering. He graduated with honours during wartime and was directed into the aircraft industry in which he spent two years in aircraft design. He then joined British Railways in the New Works design office of the then Great Western Railway working on post-war reconstruction work. This was followed by several years as an assistant resident engineer on railway maintenance in district engineering offices. He then returned to the New Works Office as a section leader.

In 1962 he was seconded by the U.K. Railway Advisory Service to the engineering consultancy of G. Maunsell& Partners in connection with the Western Australian Standard Gauge Railway Project. After the secondment he joined Maunsell to complete the Project, later taking charge of the Perth Office and becoming first an Associate and then a Director of the Australian consultancy of Maunsell& Partners. In 1975 he moved to the Melbourne Office of the company as Deputy Managing Director. He retired in 1988.

Sands was responsible for many railway engineering projects in Australia and also overseas, in Hong Kong and South Africa. In 1980 he returned to Perth for two years as the Maunsell director in the Fluor-Maunsell Joint Venture for the Dampier to Perth Natural Gas Pipeline. Later he was responsible for coordinating the international work of the three Maunsell firms based in Melbourne, Hong Kong and London. He was always very concerned with the personnel aspects of the firm and was a Trustee and Chairman of Trustees of the firm's Superannuation Fund for many years.

William Ian McCullough (1923-2001)

Ian McCullough was born in Busselton and was educated at Hale School and the University of Western Australia from which he graduated in engineering. In January 1946 he commenced work with the WAGR on a survey along the Avon Valley west of Northam, seeking a new railway route through the Darling Range. Despite being undertaken during two of the wettest years on record, the survey proved that a route with an acceptable gradient of 1 in 200 was obtainable.

McCullough joined New South Wales Government Railways in 1949 and spent two years on railway construction works before rejoining the WAGR in January 1951. He was engaged on railway survey work until appointed assistant district engineer, firstly at Narrogin, in 1952, and then at Bunbury, in 1954. In the post-war years railway maintenance work was particularly difficult as, during the war, a large backlog had accumulated and, during the 1950s, resources were limited.

In 1957 McCullough was appointed District Engineer at Bunbury where he started research into how the effective lives of critical railway fixed assets, such as rail and sleepers, affected railway renewal programmes. He became District Engineer Perth in 1961 and, in the following year, was seconded to consultants working on a feasibility study into the lowering of the railway through central Perth. In 1963 he was appointed Assistant Chief Civil Engineer Works at a time when the Standard Gauge Railway Project was in the early stages of construction. He was responsible for the location of its route which, from Merredin to Kalgoorlie, was almost all in deviation from the existing NG line. He also liaised with the consultants on the project and was responsible for the project works carried out departmentally. He also supervised the construction of the Kwinana to Jarrahdale NG railway which was built to transport bauxite from Alcoa's mine to its refinery at Kwinana.

After promotion to Chief Civil Engineer in 1966, McCullough continued his involvement in the development of railway infrastructure at Fremantle, Forrestfield and Kwinana. He helped introduce cyclic mechanised maintenance and track maintenance by contract and developed a track upgrading strategy. In 1971 he was appointed Assistant Commissioner under Commissioner Pascoe and was responsible for negotiating agreements and railway planning for a number of major resource projects involving: mineral sands, woodchips, bauxite/alumina and nickel. He also supervised construction of the Kalgoorlie to Kambalda and **??**Widgiemooltha SG railway and the Dongara to Eneabba NG railway and also the conversion to SG of the Widgiemooltha to Esperance NG railway and of the Kalgoorlie to Leonora NG railway.

McCullough was appointed Commissioner of Railways in 1978. The main thrust of his work as chief executive was the commercialisation of Westrail (the name by which the WAGR was known from 1975). His goals were to eliminate losses on freight operations and to obtain government subsidies for passenger traffic. In the freight market Westrail withdrew from the carriage of small freight, formed joint venture companies with private organisations in freight and quarry operations and negotiated freight contracts with most of its major clients.

McCullough retired as Commissioner in 1989 after one of longest periods in office of any postwar Australian railways commissioner. He was made a Member of the General Division of the Order of Australia in 1990. He died in 2001.

11 Acknowledgments

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Individuals who have contributed to the preparation of the nomination, by loan of photographs, preparation and review of drafts, responses to questions include:

Mr Patrick Sands, Mr John Hoare, Mr Bob Elliot, Mr Doug Field. Mr Field in particular provided from his personal files the documents labelled Figures 2 and 3, and a number of the photographs of construction work taken while he was in the employ of Thiess Bros Pty Ltd.

Prepared for Engineering Heritage WA by Richard Hartley and Don Young

12 References

Affleck, Fred, *On Track: The Making of Westrail, 1950-1976,* Perth, 1978.
Fearnside, G.H., *All Stations West: The Story of the Sydney-Perth Standard Gauge Railway,* Sydney, 1970.
Gordon, F.R., 'Rock cuttings for railways – Construction methods and geology', AusIMM Conference, Western Australia, 1979.
Horrigan, J.B., 'Foundations of East Perth Power Station', Paper to Institution of Engineers, Australia, Perth Division, 1936, PR11248 BL.
Le Page, J.S.H., *Building a State: The Story of the Public Works Department of Western Australia 1829 - 1985*Leederville, 1986.
Lipscombe, D., '1960-1979' in Firkins, P. (ed.), *A History of Commerce and Industry in Western Australia,* Perth, 1979.
Maunsell and Partners, 'Railway Standardisation and Associated Railway Works. Master Plan: Estimates,' Perth, March 1966 (from 'Red Master Plan').
Maunsell and Partners, Standard Gauge Project, Statistical Information. March 1965, 4 pp.
McCullough, W.I., 'Construction of the Standard Gauge Railway from Fremantle and Kwinana to Kalgoorlie', Paper to Institution of Engineers, Australia, Perth Division, 28 November 1966.
Meager, R.G. and Sands, P.G., 'The design and construction of railway embankments in bull-dust soils', *Proceedings of the Symposium on soils and earth structures in arid climates,* Adelaide,1970.
Parliament of Western Australia, Railway Standardisation Agreement Act No. 26 of 1961.
The Railway Gazette, 'Freight Terminal at Kewdale', 21 June 1968, pp. 453-54, 456.
*The Railway Gazette, '*Western Australia completes its Standard Gauge Project', 20 September 1968, pp. 689-92.
WAGR Co-ordinator of Standard Gauge Planning, 'Report on Standard Gauge Project as at 30th June 1964', Perth, 7 October 1964.
WAGR/ Westrail booklets:

- 'Great Standard Gauge Railway takes shape', 1965.
- 'New Lifeline', February 1966 for first traffic on dual gauge track from Northam to Perth.
- 'The Kewdale- Forrestfield Complex', 1968-1969.
- 'Inauguration of Perth- Port Pirie Standard Gauge Passenger Service', June 1969.
- 'Progress and Achievement: Western Australian Government Railways', 1970.
- **'**Project Completed',1972 for commissioning of the Forrestfield NG automatic hump retarder marshalling yard, final contract of the SGR project.
- 'Westrail Achievements', 1976; opening of Westrail Centre, administrative headquarters.

Appendix A

Significant Project Dates

18 Nov. 1960	WA Government announces agreement with BHP for establishment of iron and steel industry dependant on ratification of Koolyanobbing-Kwinana SG railway.
26 Aug. 1961	Federal Parliament confirms rail standardisation plan and Railway Standardisation Agreement of 1961.
5 Nov. 1962	WA Premier, Hon. David Brand, detonates an explosive charge in the Avon Valley to mark the start of the Standard Gauge (SG) Railway Project.
15 Feb.1966	Opening of the Avon Valley railway for Narrow Gauge (NG) operations.
11 Nov. 1966	SG grain traffic from Merredin to Leighton Yard (N. Fremantle) commences.
10 Apr. 1967	First iron ore train on SG railway from Koolyanobbing to Kwinana.
3 Aug. 1968	SG railway from Kwinana and Fremantle linked to Trans-Australian railway at Kalgoorlie.
2 Nov. 1968	First SG freight train leaves Port Pirie for Leighton.
15 Jun. 1969	First SG passenger train from Port Pirie arrives at, and departs from, Perth Passenger Terminal.
Nov. 1969	Completion of SG railway link between Broken Hill (NSW) and Cockburn (South Australia).
15 Jan. 1970	First SG transcontinental freight train leaves from Sydney for Perth.

Appendix B

Standard Gauge Railway Project
Major Building Works Contracts

Contract	Works	Contractor	Date
C11	Avon Yard & West Toodyay Yard buildings	Cooper & Oxley	1956-66
C12	Merredin Yard buildings	Consolidated Constrn	1965-6
C24	Forrestfield Loco Depot	Jennings	1967-68
C29	Robb Jetty Freight Terminal	Jaxon Construction	1970-71
C31	Forrestfield Wagon Repair Depot	Jennings	1968-69
C33	Forrestfield Loco Super/Yard-mstr's Offices	Sabemo	1969
C36	East Perth Rail Car Depot	Sabemo	1968
C37	Forrestfield Carriage Shed	Jaxon Construction	1969-70
C42	Kewdale Freight Terminal 1	James Wallace	1968-69
C43	Kewdale Freight Terminal 2	PDC Construction	1969-70
C44	Kewdale Freight Terminal 3	James Wallace	1969
C51	West Kalgoorlie Yard buildings	James Wallace	1970
C61	KewdaleRefrig Van Servicing Depot`1	James Wallace	1968
C62	KewdaleRefrig Van Servicing Depot 2	Fairweather	1970

APPENDIX C:

SEE NEXT PAGE FOR INTERPRETATION PANEL


ONE RAILWAY GAUGE COAST TO COAST
COMPLETION OF KALGOORLIE TO PERTH LINK
Historical Development
Project Planning, Design and Construction
Eminent Persons Associated With The Project
Avon Valley Deviation
Public Transport Authority

Appendix D

Additional Illustrations

STANDARD GAUGE RAILWAY PROJECT

5th November 1962 – Official Opening of Project on Monument Hill

The Premier, Sir David Brand, with Charles Court looking on, about to push plunger to initiate the blast to start excavation of the Main Cutting. The track to the right is the centerline of the proposed railway.

This plaque was unveiled by the Hon. David Brand M.L.A. Premier of Western Australia, on 5th November, 1962, to mark the commencement of work on the Kwinana – Kalgoorlie Standard Gauge Railway, under the Commonwealth – State Agreement. Hon. C W Court, Minister for Railways, Western Australia, Hon. H. Opperman, Commonwealth Minister for Shipping and Transport, G.C.G. Wayne, Commissioner, Western Australian Government Railways, K.A.Smith, Commissioner Commonwealth Railways, G. Maunsell and Partners, Consulting Engineers.

Blasting at Monument Hill cutting C1A Contract 1963

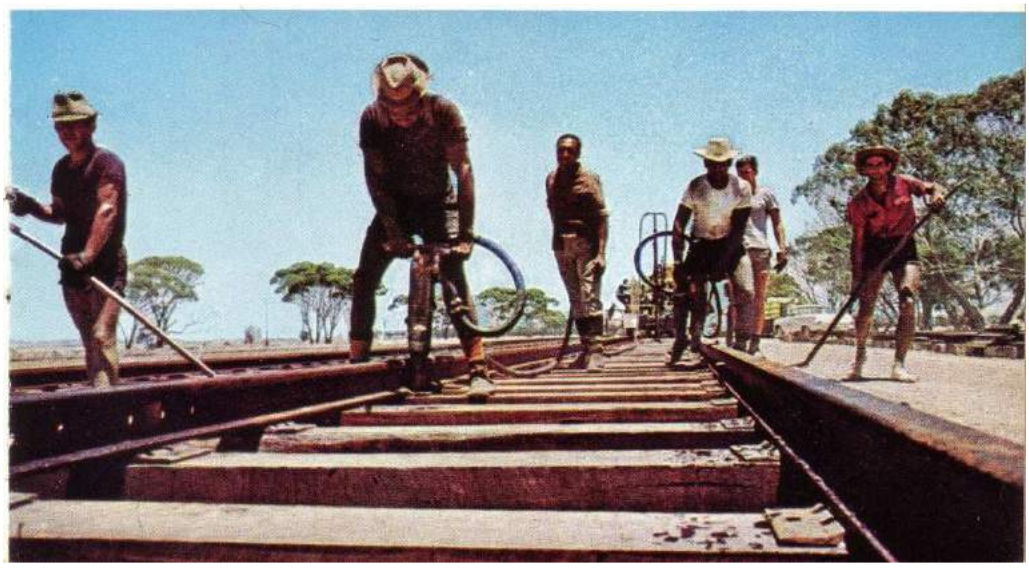
Excavating at Monument Hill cutting C1A contract 1963

Wooroloo Brook bridge under construction

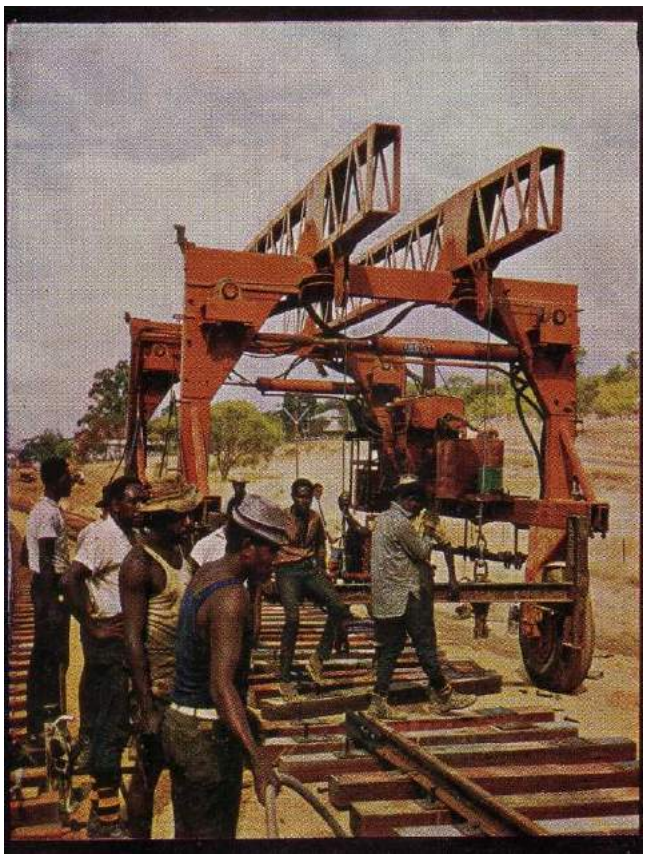
Northam Bridge for Great Southern Railway deviation over the Avon River

Cut and fill earthworks operations on C8 contract 1964, east of Northam

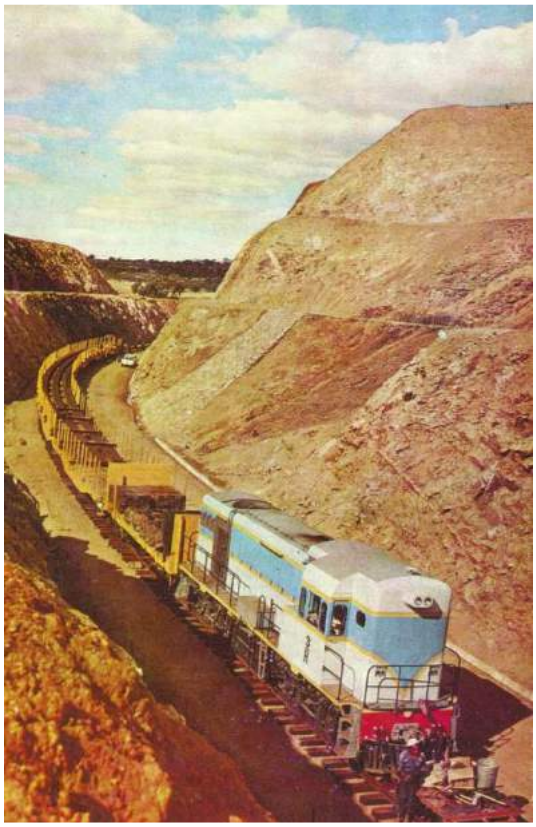
Compacting railway formation C8 contract 1964, east of Northam



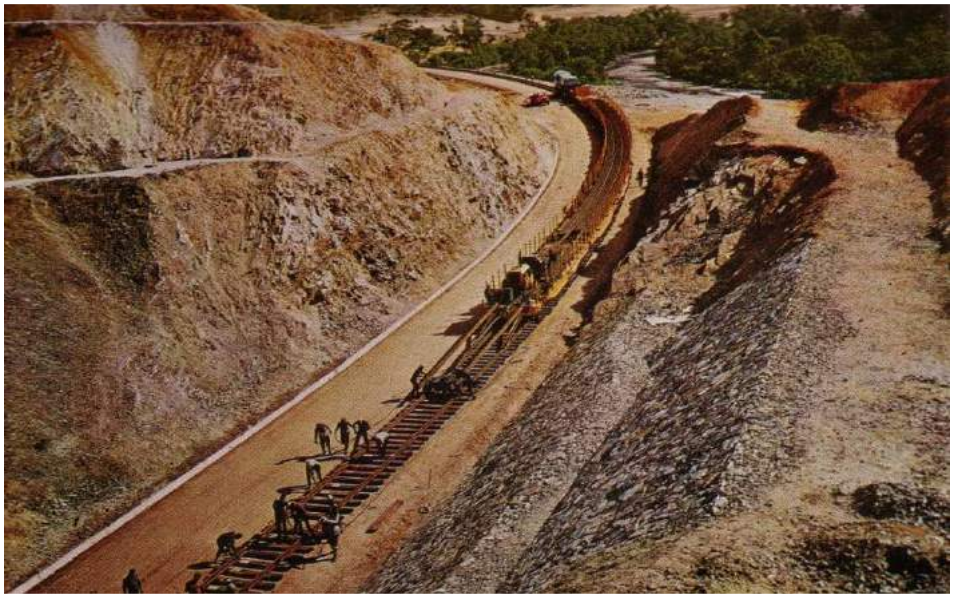
Thursday Islanders track laying



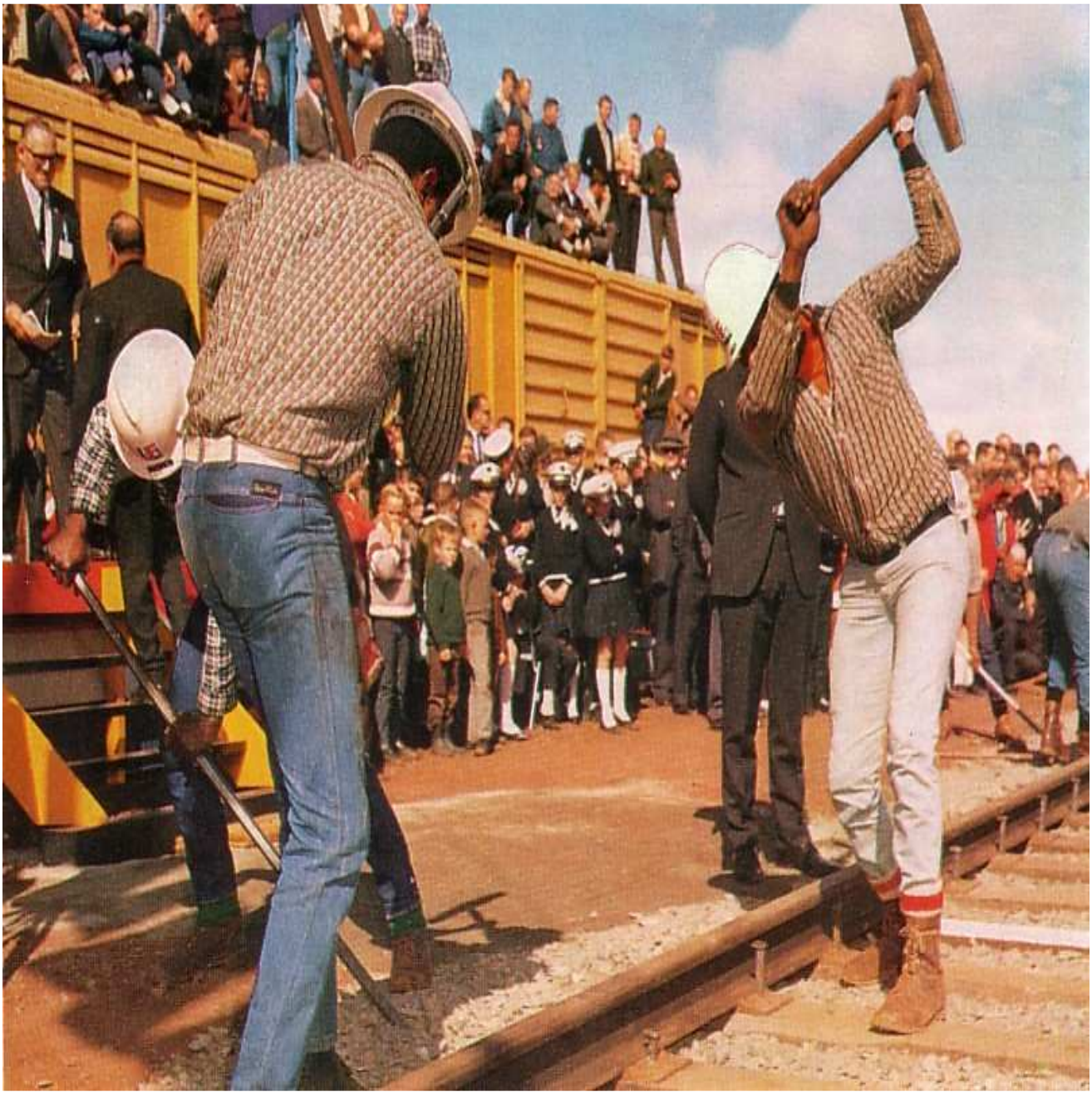
Track laying in the Avon Valley



Track laying train in Windmill Hill cutting near Toodyay



Track laying in Windmill Hill cutting



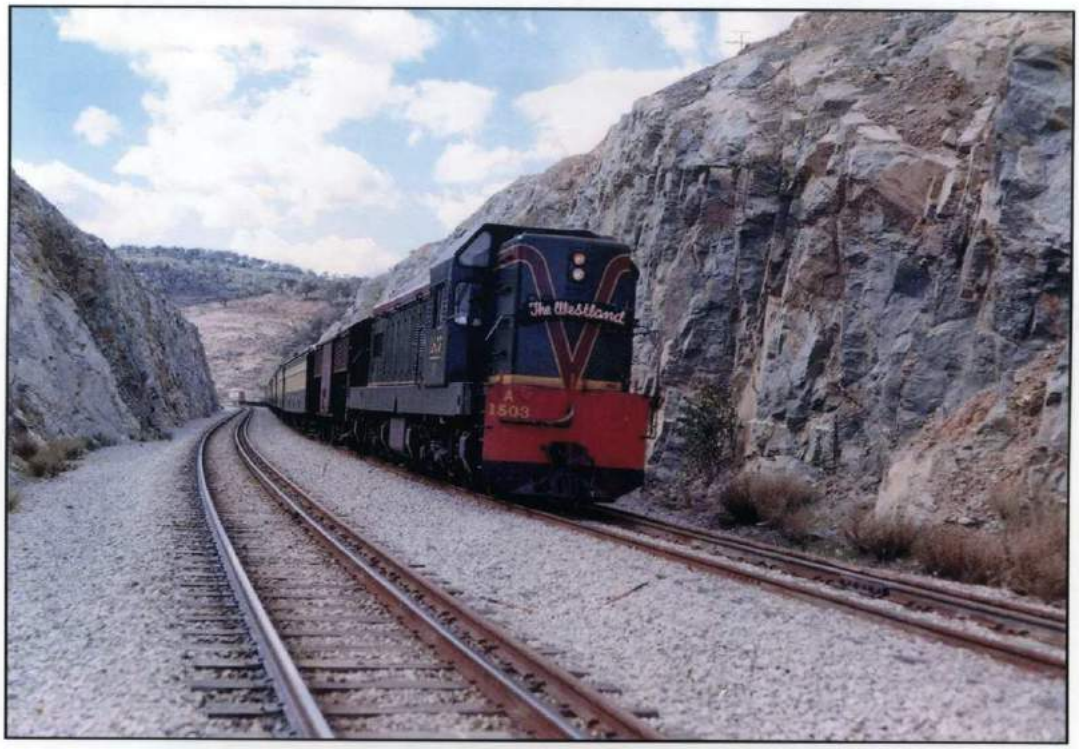
Thursday Islanders lay last section of rail at Kalgoorlie

The Hon. David Brand drives the last “gold” spike to officially link the standard gauge railway at Kalgoorlie, 3rd August 1968. (*The West Australian newspaper photo*)

Forrestfield Locomotive Depot

First wheat train leaves Merredin 11 November 1966

STANDARD GAUGE RAILWAY



The 'Westland' entering the Monument Hill Cutting in the late 1960s

An aerial view of a freight train in the Avon Valley

Indian Pacific Train passing through the Avon Valley

Wheat Train passing through cutting in the Avon Valley